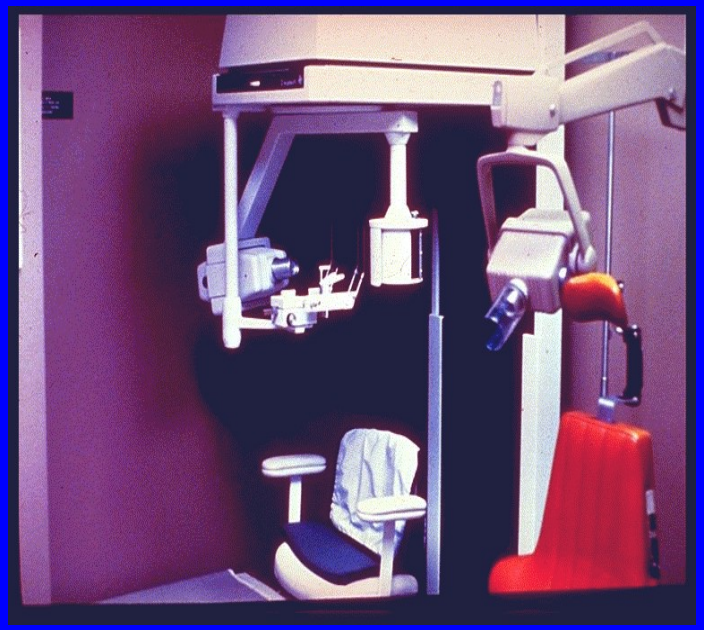
Radiation Safety Training



Annual Requirement For:

- Worker's safety
- Worker's right to know
- Patient safety issues
- Regulatory issues

Naturally Occurring Radiation Sources

- Primordial radionuclides & their radioactive decay products
- Cosmic rays
- Cosmogenic radionuclides

Cosmic Rays

- Primary extraterrestrial radiation
  - ~10 GeV particulate radiations (charged particles, heavy ions)
  - galactic & solar origins
- Secondary radiations
  - produced by cosmic ray interactions with atmosphere
  - electrons, muons, photons, neutrons, etc.

Naturally Occurring Sources of Radiation Exposure

Source	Type of Exposure Tissue Exposed	Effective Dose Rate (mrem/yr)	~ % of Total
Primordial Radionuclides			
1. Inhaled (mostly Rn-222 and daughter products	internal; bronchial epithelium	200	68
2. Ingested (mostly K-40)	internal; whole body	40	13
3. External (from terrestrial radiouclides)	external; whole body	28	9
Cosmic rays	external; whole body	27	9
Cosmogenic Radionuclides	internal; whole body	< 1	<1
Total:		~300	100

Technology Enhanced Natural Sources of Radiation Exposure

*smokers

Source	Type of Exposure Tissue Exposed	Effective Dose Rate (mrem/yr)	% of Total (Nonsmoking)
Smoking (Po-210)	internal; bronchial epithelium	280 (*1300)	NA
Domestic water supply (rado	internal; bronchial epithelium	3	5
Building materials	Mixed external & internal; multiple sites	3	5
Mining & agricultural product	Mixed external & internal; multiple sites	<1	<1
Combustible fuels	Mixed external & internal; multiple sites	<1	<1
Other consumer products	Mixed external & internal; multiple sites	<1	<1
Total:		~7	12%

Technology Produced Sources of Radiation Exposure

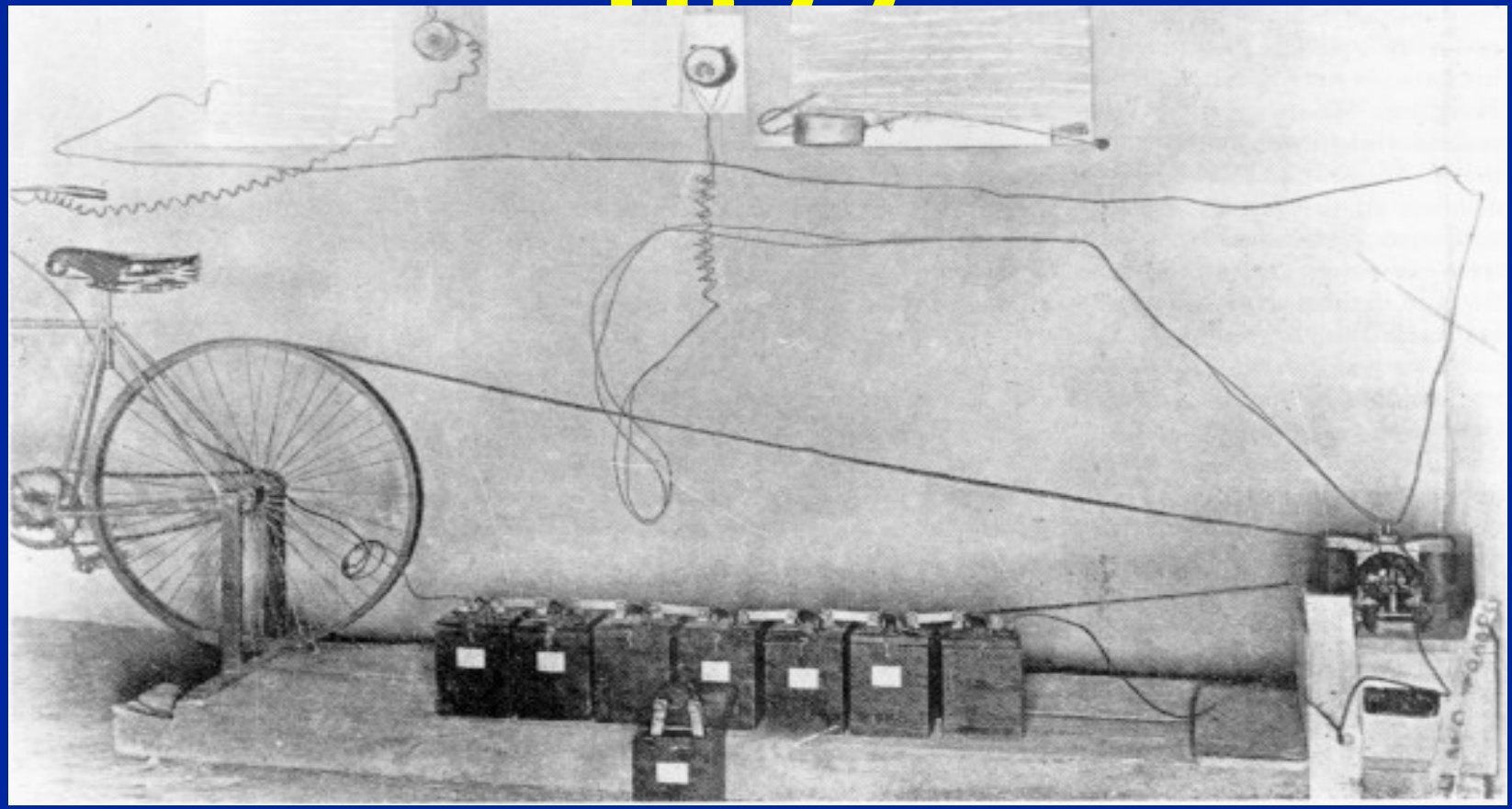
Source	Type of Exposure Tissue Exposed	Effective Dose Rate (mrem/yr)	% of Total
Medical x-rays	External, multiple sites	39	65
Nuclear medicine	Internal, multiple sites	14	24
Fallout	Mixed external & internal; multiple sites	<1	<1
Misc environmental source	Mixed external & internal; multiple sites	0.06	<<1
Nuclear power	Mixed external & internal; multiple sites	<0.05	<<1
Total		~54	~88%

The New Technology

- Nov. 8, 1895 - Wilhelm Conrad Roentgen publishes X-Ray paper

- 1896: Becquerel / Curie discovered radioactivity and separated radium

Medical Use of X-Rays 1899



Medical Use of X-Rays 1899

The New Hazard

YEAR		RADIATION INJURY
1896	(Jan)	Dermatitis of Hand
1896	(Mar)	Smarting of eye (Edison)
1896		Epilation
1897		Constitutional symptoms
1903		Bone growth inhibited
1903		Sterilization
1904		Blood Changes
1906		Bone marrow changes

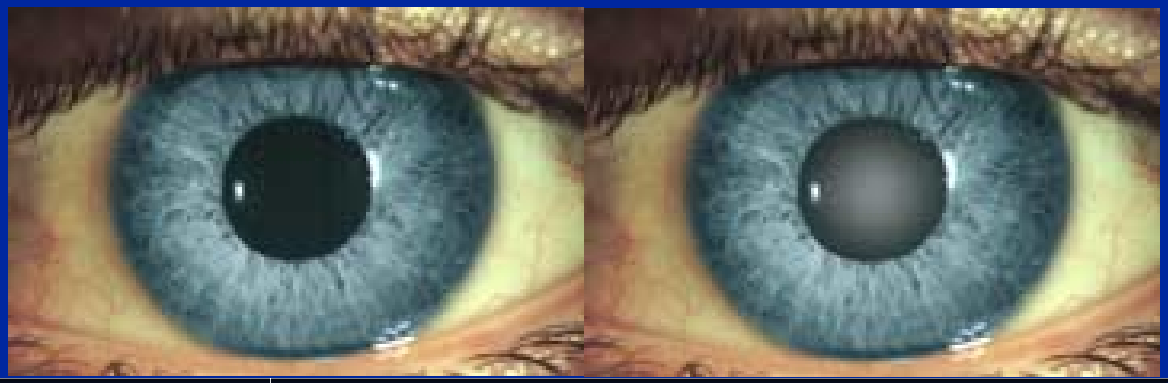
Thomas Edison and his unfortunate assistant Mr. Dally

Early Effects

- **Skin burns, necrosis**
- **Hair loss**
- **Hematopoietic effects**
  - Nausea
  - Acute Radiation Syndrome

Late Effects

- Cataracts
- Genetic
- Cancer



Observed Late Effects

- **Radium "tonic" killed some of its users, leading to FDA**
- **Radium Dial Painters**
  - Women luminuous dial painters ingested radium
  - High rate of bone cancer

Observed Late Effects

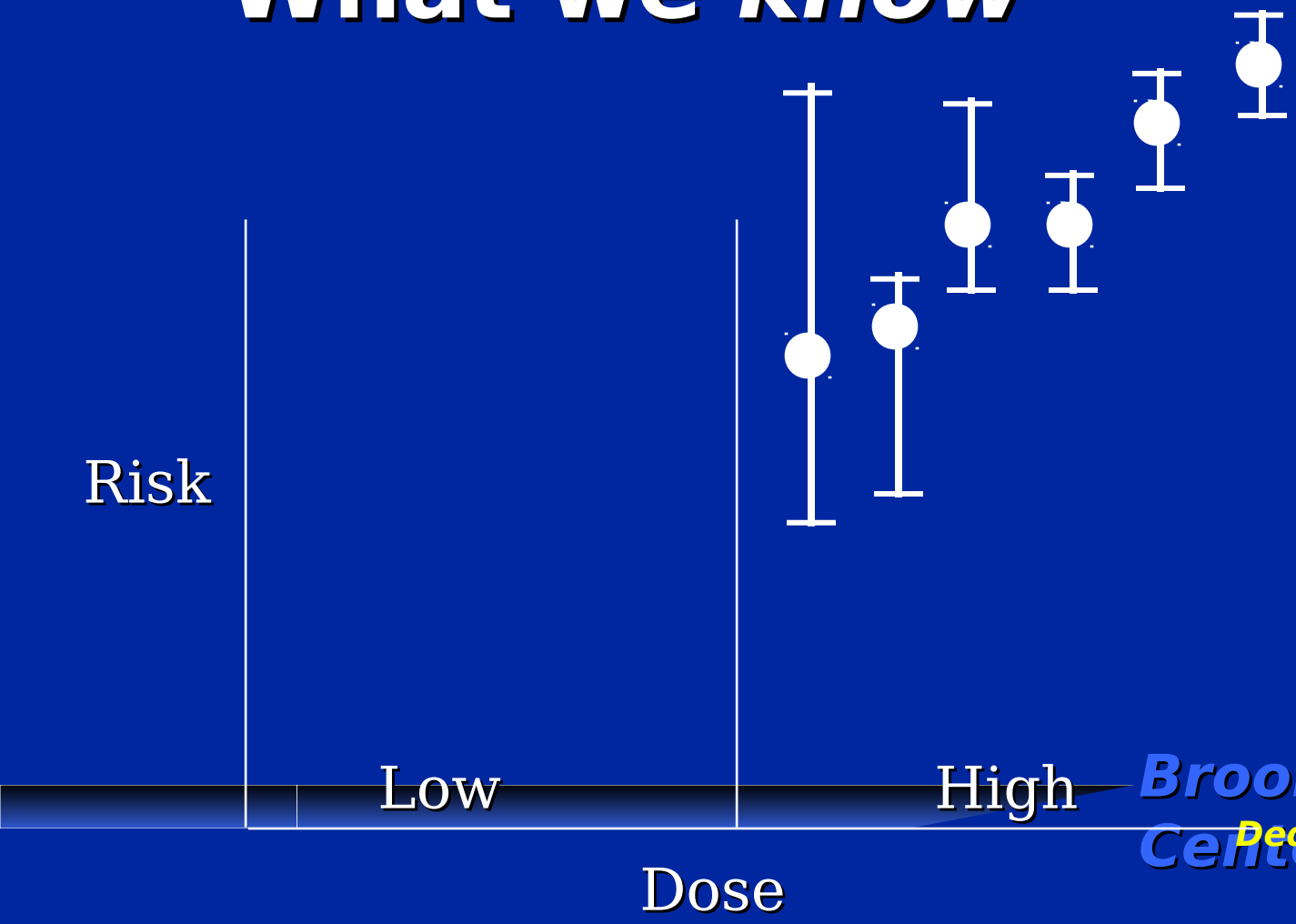
- **Leukemia deaths 1929-1943**
  - Radiologists: 8 out of 175
  - Non-radiologist: 221 out of 55,160

  Relative risk: 10.3:1
- **Leukemia deaths 1948-1963**

  Relative risk: 4:1

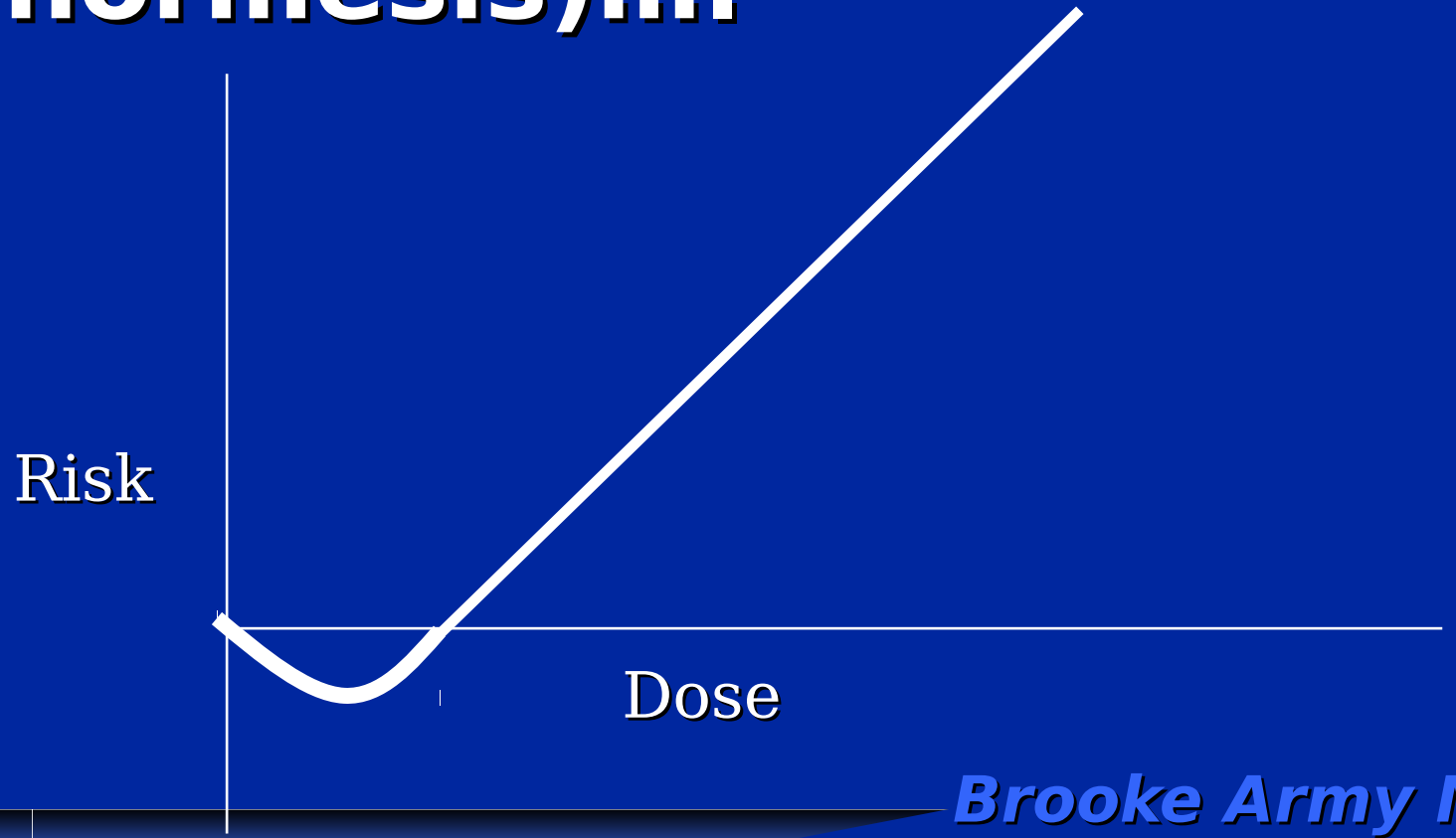
Dose Response Relationships

- **What we *know***



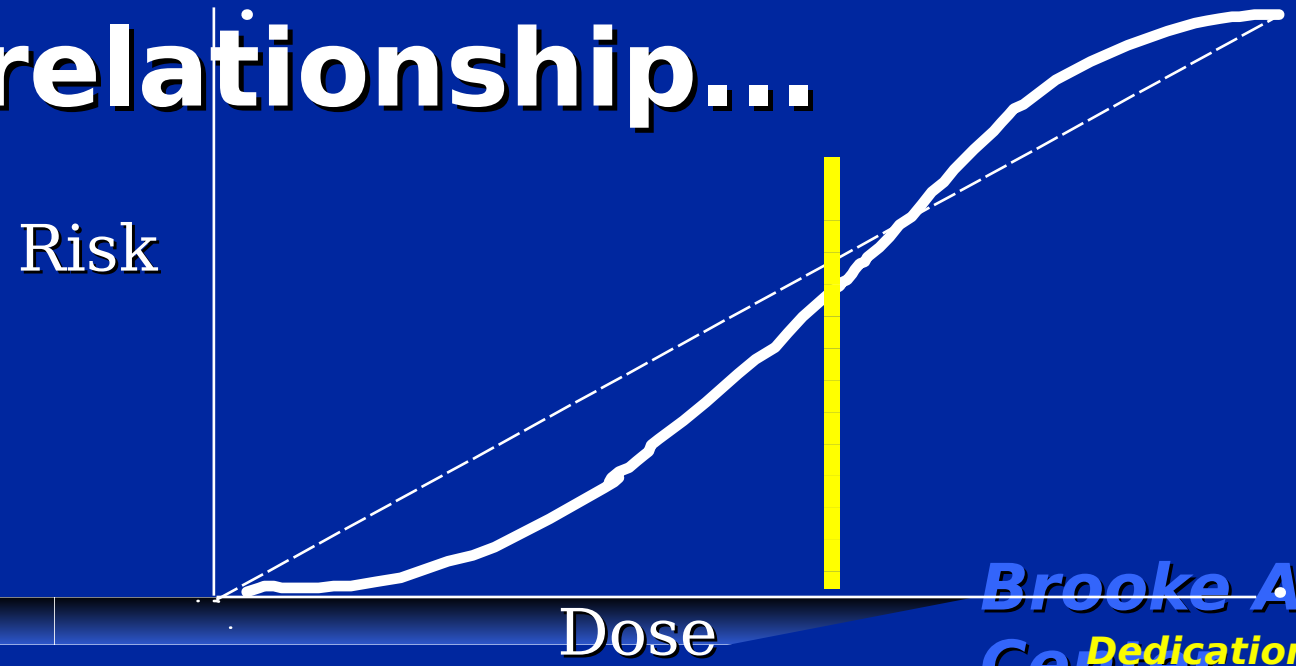
Dose Response Relationships

- What some *propose* (hormesis)….



Dose Response Relationships

- Many suspect a linear-quadratic dose response relationship…



Dose Response Relationships

- **What we *assume*...**

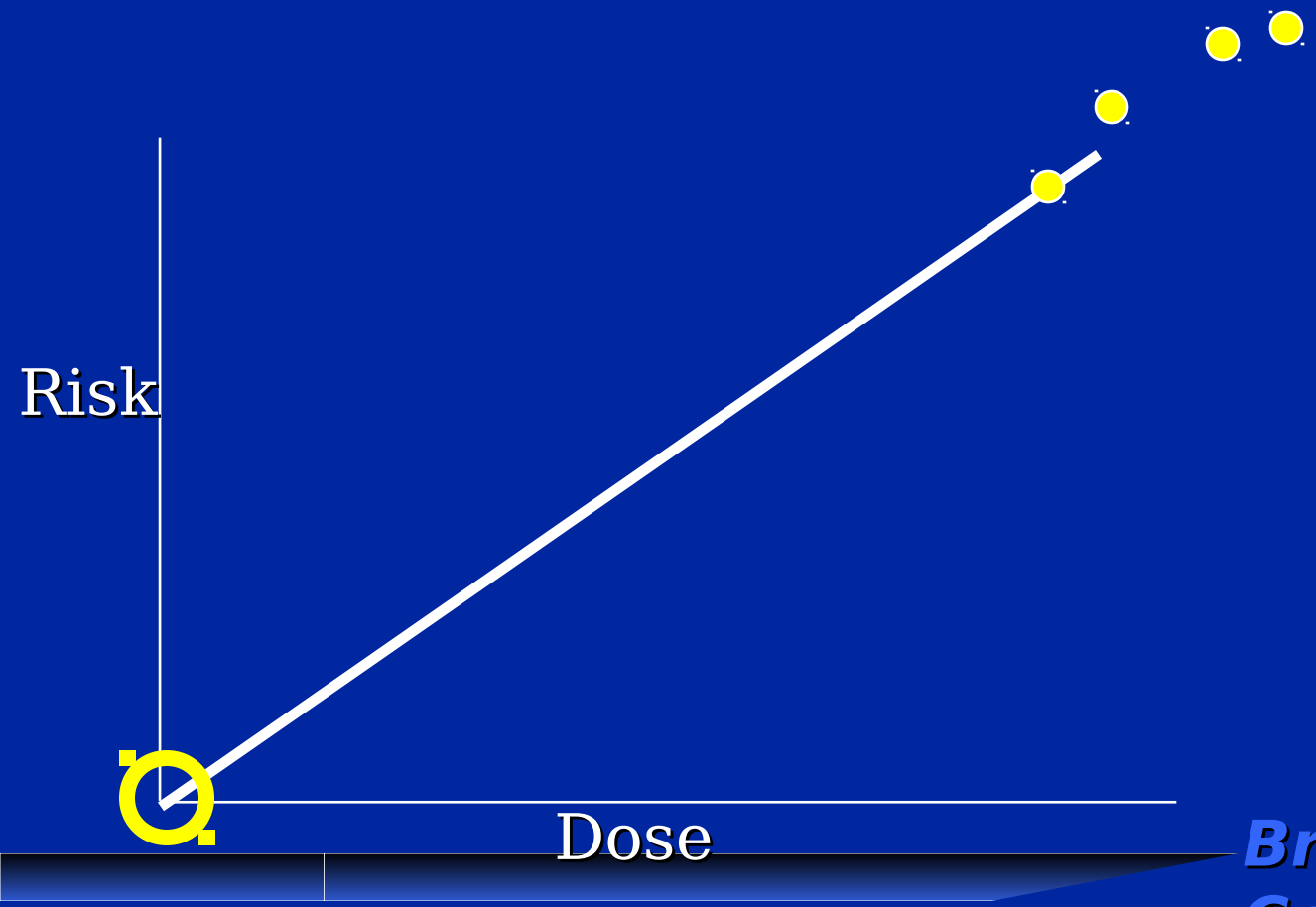


Table 1 Estimated Loss of Life Expectancy from Health Risks[a]

From: INSTRUCTIONS TO WORKERS

Health Risk	*Estimate of Life Expectancy Lost (average)*	
Smoking 20 cigarettes a day		6 years
Overweight (by 15%)		2 years
Alcohol consumption (U.S. average)		1 year
All accidents combined		1 year
Motor vehicle accidents	207 days	
Home accidents	74 days	
Drowning	24 days	
All natural hazards (earthquake, lightning, flood, etc.)		7 days
Medical radiation		6 days
Occupational Exposure		
0.3 rem/y from age 18 to 65	15 days	
1 rem/y from age 18 to 65	51 days	

[a]Adapted from Reference 10.

8.29–9

NRC Web Site or e-mail HPS

Table 2 Estimated Loss of Life Expectancy from Industrial Accidents[a]

Industry Type	*Estimated Days of Life Expectancy Lost (Average)*
All industries	60
Agriculture	320
Construction	227
Mining and Quarrying	167
Transportation and Public Utilities	160
Government	60
Manufacturing	40
Trade	27
Services	27

"...the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out." 1990 BEIR V REPORT

On the other hand, it is possibly that a small segment of the population is uniquely susceptible to ionizing radiation.

Staying Within Limits is Not Sufficient

As
Low
As
Reasonably
Achievable

ALARA

Occupational Exposure Control

- **Preclude *deterministic* effects**
  - Cataracts
  - Skin burns
  - Transient hematopoietic
  - **Necrosis**
  - **Alopecia,**
- **Minimize *probabilistic* effects (cancer teratogenic, genetic)**

Fetal Exposure Considerations

- First Two Weeks
  - At high doses: fetal death
- Weeks 2-15
  - Major organs are developing
  - High doses can cause congenital abnormalities, especially in the brain

Fetal Exposure Considerations

- **Weeks 16 until birth**
  - Risks similar to the risks for a newborn
- **Occupationally: Limit = 0.5 rem**
  - Fetus treated as member of the public
  - Mother must declare pregnancy
  - Controlled to 50 mrem/month to spread dose across the 9 months

Pregnant Patients

- Exposures of patients
  - No fetal effects detected at <10 rem
  - >10 rem is a patient-physician decision
- Unplanned fetal exposures during therapy can easily exceed 10 rem
- Diagnostic procedures usually <10 rem
- Pre-planning greatly reduces doses

Dose Limits

- To minimize probabilistic effects:
  - Total Effective Dose Equivalent: 5 rem/year
  - Fetus: 0.5 rem for the gestation period
- To prevent deterministic:
  - Lens of eye: 15 rem/year
  - Skin, Extremity or Organ: 50 rem/year

Safety Program Elements

- Administrative controls
  - Radiation Control Committee (RCC)
  - SOPs & Training
- Engineered controls
  - Facility & Equipment
  - Personal protective equipment
  - Dosimetry

Regulatory Basis

- Federal Regulation
  - CFR Titles 10 (NRC); 21 (FDA); 29 (OSHA)
  - BAMC's Nuclear Regulatory Commission License
- Army Regulation
  - AR 11-9 The Army Radiation Safety Program
  - DA Pamphlet 40-18 *(*Personnel Dosimetry Guidance)
  - TB Med 521
- BAMC Memorandum 40-72 & SOPs

- BAMC Memorandum 40-72 & SOPs

Part 19 of 10 CFR: Notices, instructions and reports to workers.

UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICE LOCATIONS

A representative of the Nuclear Regulatory Commission can be contacted by employees who wish to register complaints or concerns about radiological working conditions or other matters regarding compliance with Commission rules and regulations at the following addresses and telephone numbers.

REGIONAL OFFICES

REGION	ADDRESS	TELEPHONE
I	U.S. Nuclear Regulatory Commission, Region I 475 Allendale Road King of Prussia, PA 19406-1415	(800) 432-1156
II	U.S. Nuclear Regulatory Commission, Region II Atlanta Federal Center 61Forsyth Street, S.W., Suite 23T85 Atlanta, GA 30303-3415	(800) 577-8510
III	U.S. Nuclear Regulatory Commission, Region III 801 Warrenville Road Lisle, IL 60532-4351	(800)522-3025
IV	U.S. Nuclear Regulatory Commission, Region IV 611 Ryan Plaza Drive, Suite 400 Arlington, TX 76011-8064	(800) 952-9677

To report safety concerns or violations of NRC requirements by your employer, telephone: **NRC SAFETY HOTLINE** **1-800-695-7403**	To report incidents involving fraud, waste, or abuse by an NRC employee or NRC contractor, telephone: **OFFICE OF THE INSPECTOR GENERAL** **HOTLINE** **1-800-233-3497**

Dosimetry Program

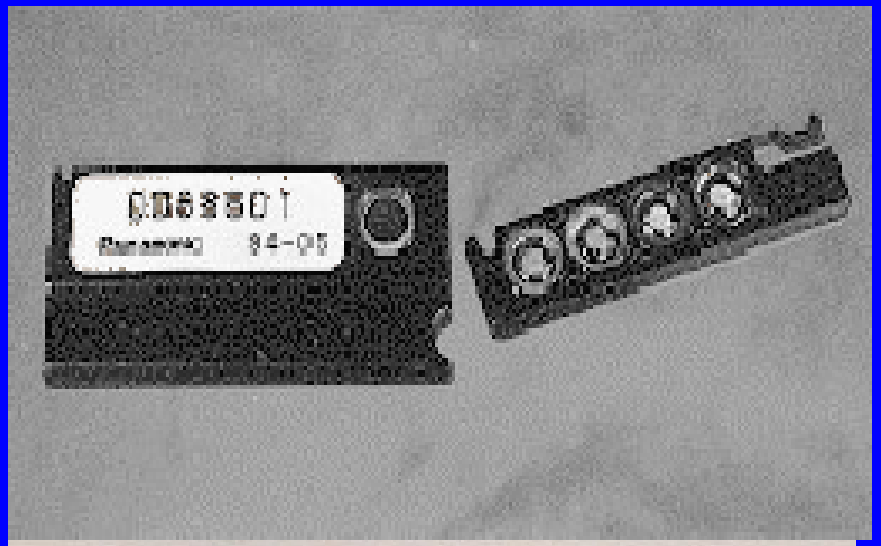
Required when the employee may exceed 10% of any limit

QUARTERLY ALARA INVESTIGATION LEVELS

CATEGORY	LEVEL 1	LEVEL 2 (RCC Review)
Whole Body	125 mrem	375 mrem
Eye	375 mrem	1126 mrem
Skin/extremity	1250 mrem	3750 mrem

The Radiation Safety Officer or designee will

- Conduct an investigation.
- Determine the cause, timeframe, and circumstances.
- Recommend corrective actions.

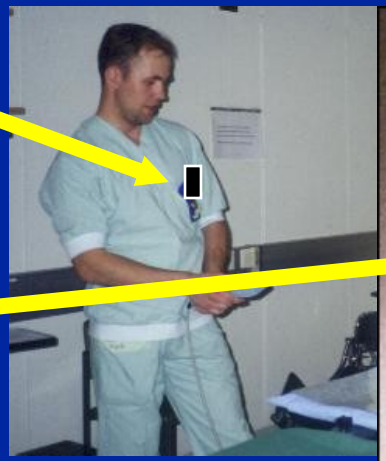


- Storage
  - With control badge
- Tampering
  - Don't
  - Punishable under UCMJ
- Lost badges
  - Report promptly

Dosimetry Clerk
Pat Brown
295-2338
Clinic Coordinators

One Badge System

- Worn between waist and neck
- When wearing lead apron, worn outside apron



Two Badge System

- Waist badge under apron
- Collar badge outside apron
- Required for fluoroscopy

Reports Quarterly & Annually

- Archived at the AIRDC
- Available at Health Physics Service

PCN V60QD10034A FOR OFFICIAL USE ONLY
PRIVACY ACT DATA

DATE 06/23/95 ANNUAL/QUARTERLY HISTORY OF EXPOSURE TO IONIZING RADIATION PAGE 001

NAME DOE, JOHN Q.
SSN 000-00-0000
DATE OF BIRTH 07/01/59
OCCUPATION CODE
SEX
PERMISSIBLE LIFETIME DOSE 085.000

ALL DOSES REPORTED IN REM

PERIOD WORN FROM	TO	ACCT NR	DOS NR	DOS CD	NOTE CD	DOSE THIS PERIOD SHALLOW	EYE	DEEP	DOSE THIS QTR SHALLOW	EYE	TEDE	DOSE THIS YEAR SHALLOW	EYE	TEDE	LIFETIME TEDE
01/08/95	02/11/95	AFI	0153506	AA		000.043	000.041	000.035							000.536
01/08/95	02/11/95	AFI	0144176	DA		000.046	000.045	000.044	000.046	000.045	000.044	000.046	000.045	000.044	000.580
01/10/95	02/09/95	AFI	0000000	BG	H	000.310			000.310			000.310			
02/12/95	03/09/95	AFI	0073257	AA		000.033	000.031	000.031	000.079	000.076	000.075	000.079	000.076	000.075	000.610
02/12/95	03/09/95	AFI	0079275	DA		000.012	000.011	000.008							
02/10/95	03/09/95	AFI	0000000	BG	H	000.140		000.000	000.450			000.450			
03/10/95	04/09/95	AFI	0000000	BG	H	000.460		000.000	000.910			000.910			
03/12/95	04/08/95	AFI	0066501	AA		000.015	000.015	000.015							
03/12/95	04/08/95	AFI	0100930	DA		000.020	000.019	000.018	000.099	000.095	000.093	000.099	000.095	000.093	000.703

THIS REPORT IS FURNISHED TO YOU UNDER THE PROVISIONS OF THE U.S. NUCLEAR REGULATORY COMMISSION REGULATIONS (10 CFR 19) OR THE DEPARTMENT OF LABOR REGULATIONS (29 CFR 1910). YOU SHOULD PERSERVE THIS REPORT FOR FUTURE REFERENCE.

AFI BROOKE ARMY MEDICAL CENTER
HEALTH PHYSICS OFFICE
MCHE-DHR
BUILDING 1188
FORT SAM HOUSTON TX 78234-6390

Occupational Exposures

Occupational Category	Average Annual Total Effective Dose (mrem)
1. Uranium Miners	2,300
2. Nuclear Power Operators	550
3. Radiotherapy	260
4. Airline Crews	170
5. Diagnostic Radiology & Nuclear Medicine	100
6. Radiology Special Procedures	1,800
7. Cardiology (Cardiac Catheterization)	1,600

Radiation Protection From X-Rays

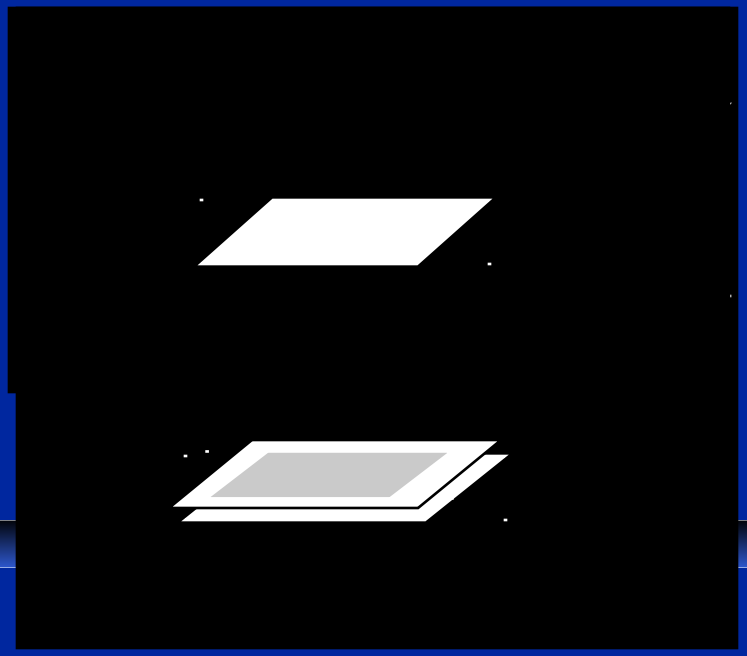
- Patient protection
- Staff protection

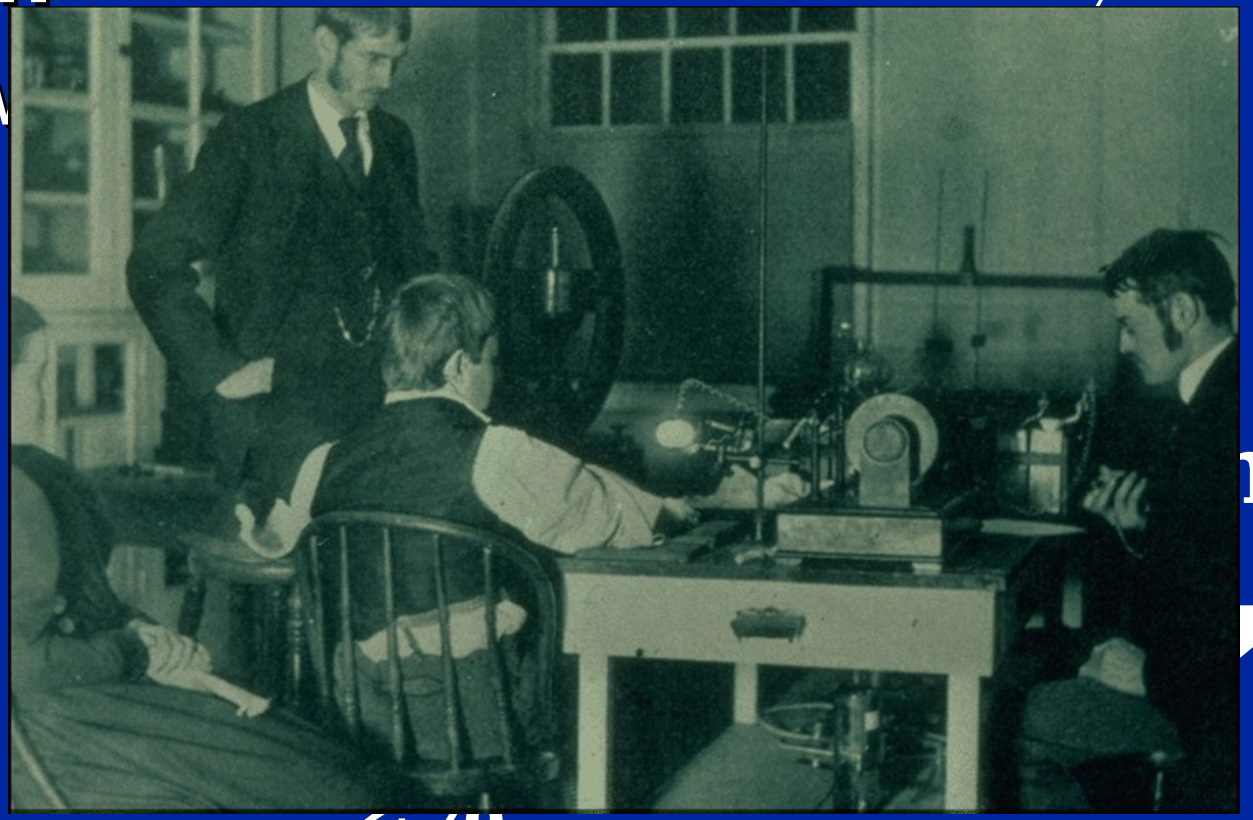
Patient Safety

- Cost/benefit basis for exposure
- Quality assurance programs
- Personal protective equipment
- Dose reduction techniques and equipment design

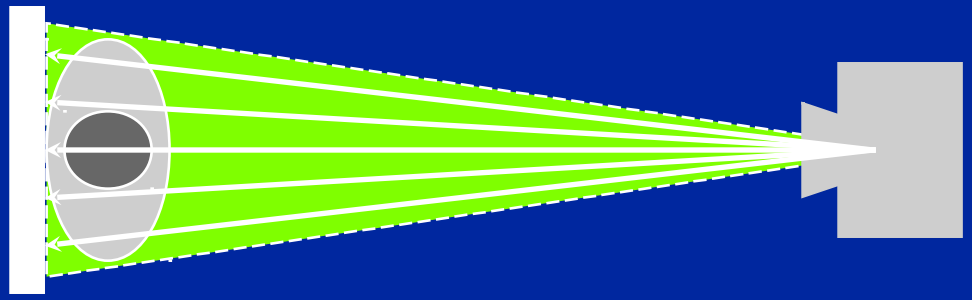
Equipment Design/Performance

- **Beam Filtration**
  - Remove non-penetrating low energy x-rays.
- **Collimation**

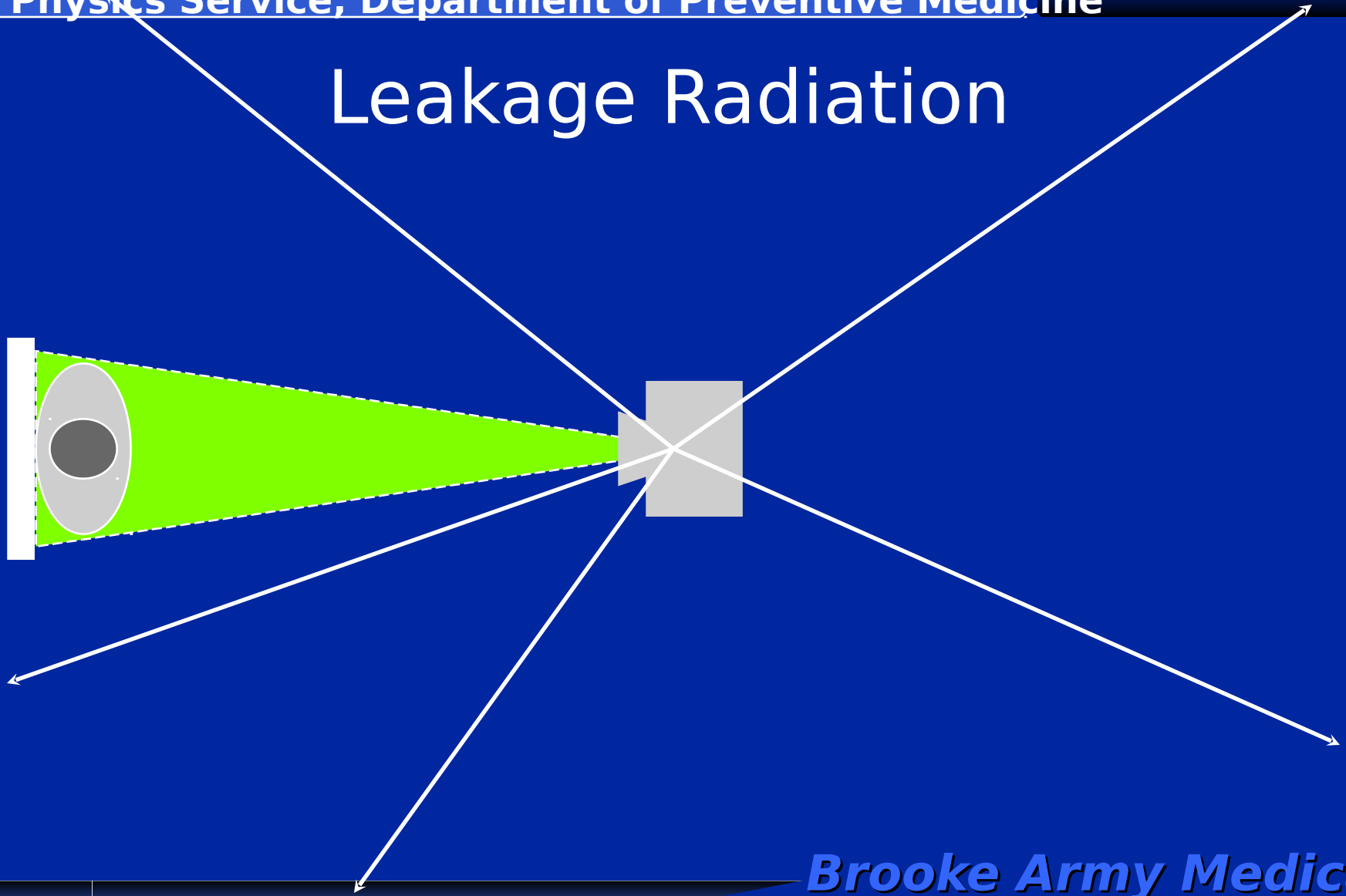




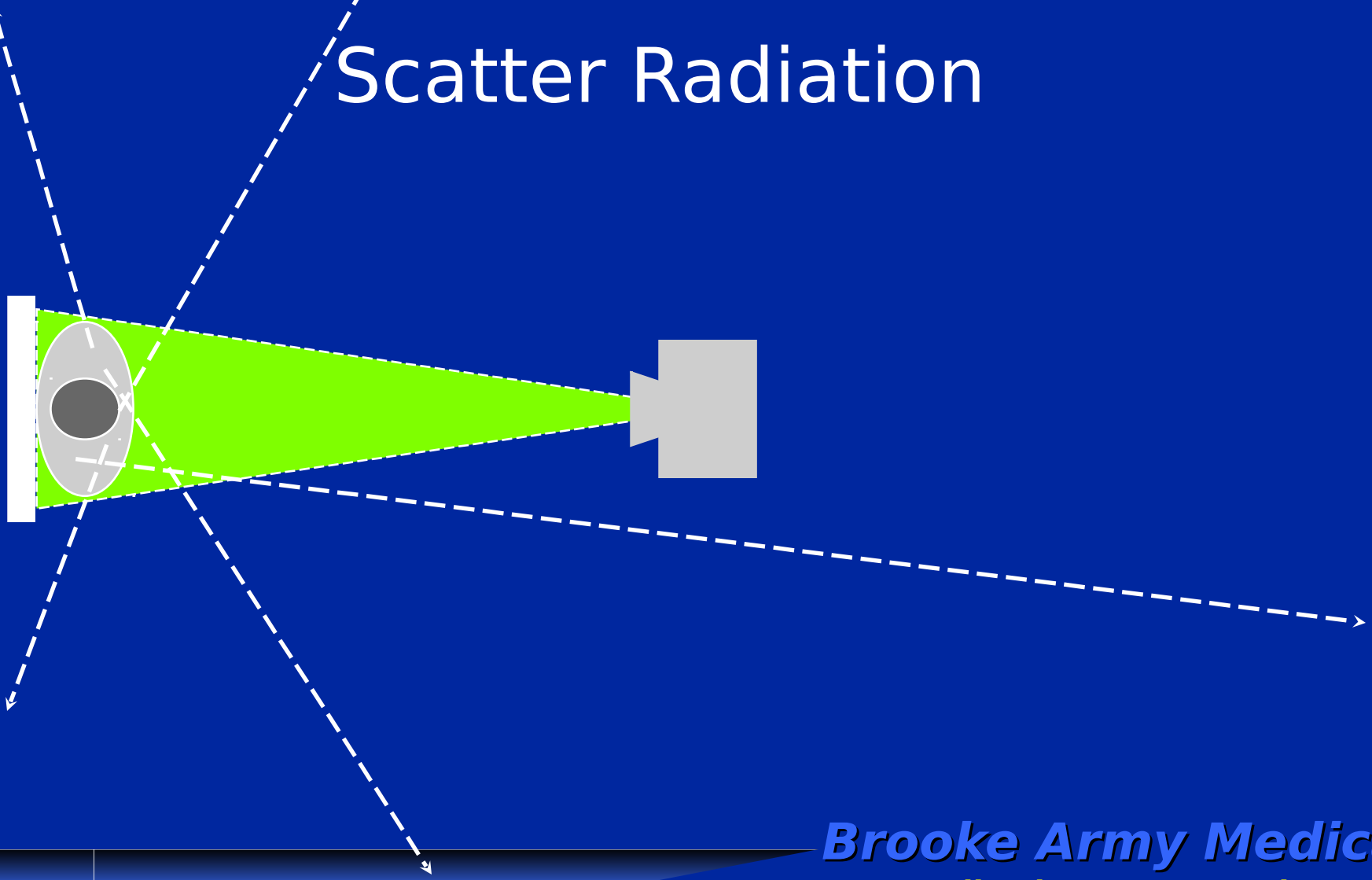
Primary Radiation



Leakage Radiation



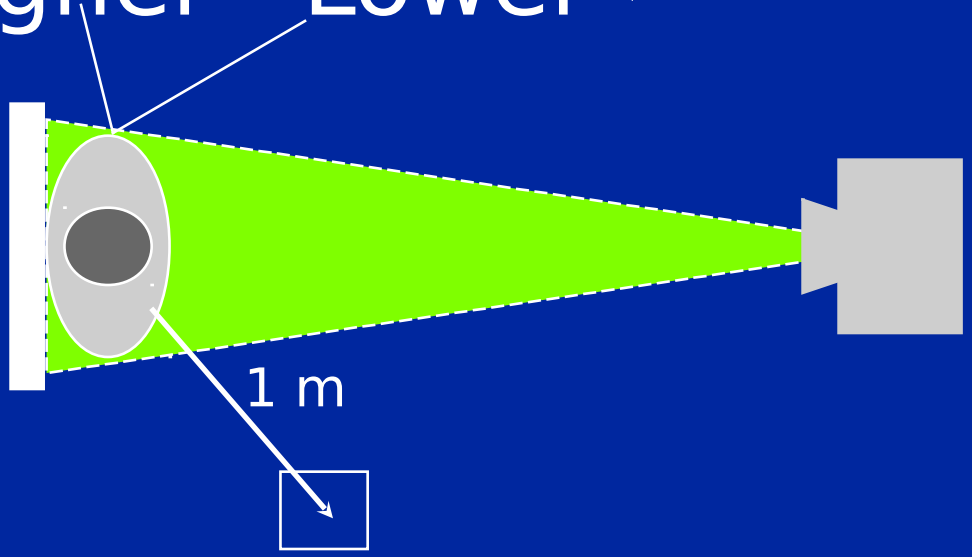
Scatter Radiation



Scatter Radiation

Scatter ~ 0.0015 (0.15%) incident at 1 m from the patient (400 cm² field)

Higher ← Lower



Energy and intensity has angular dependence

Basic Radiation Protection Principles

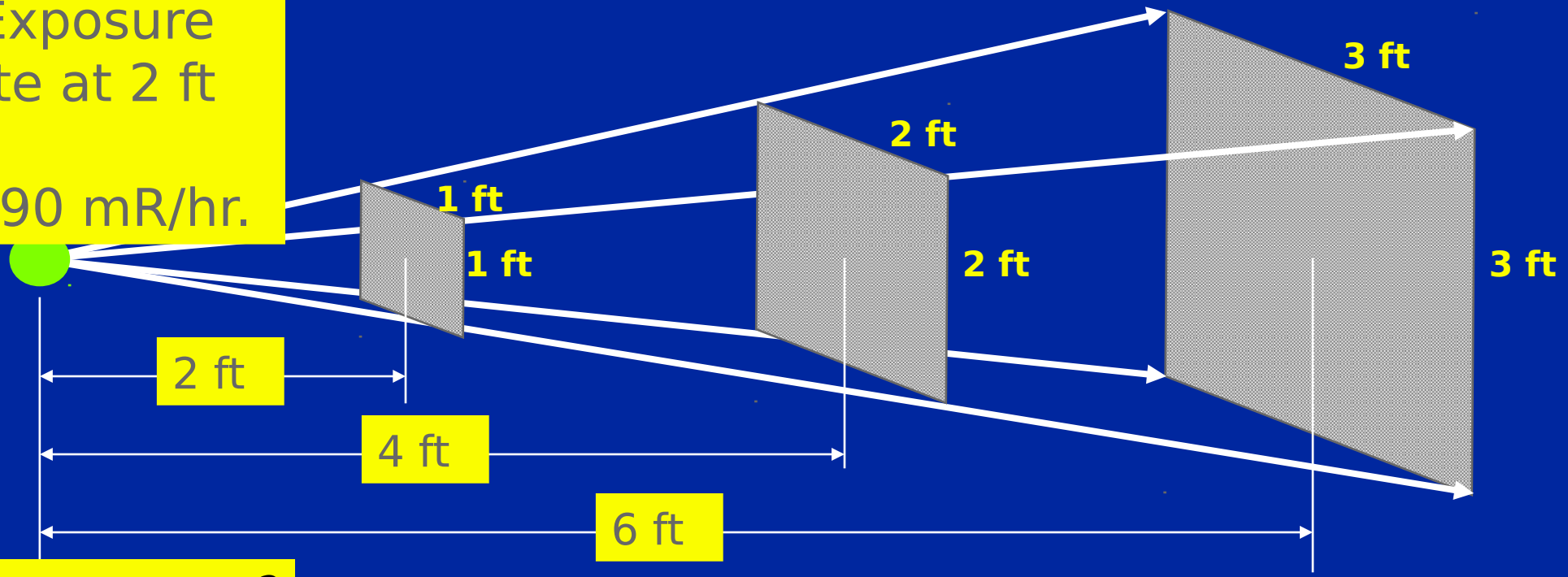
- Time
- Distance
- Shielding
- Source term reduction

Fluoroscopy

- After 5 minutes of expos
  - Audible signal or
  - System shuts off
  - Must be manually rese

Given:
Exposure
Rate at 2 ft

= 90 mR/hr.

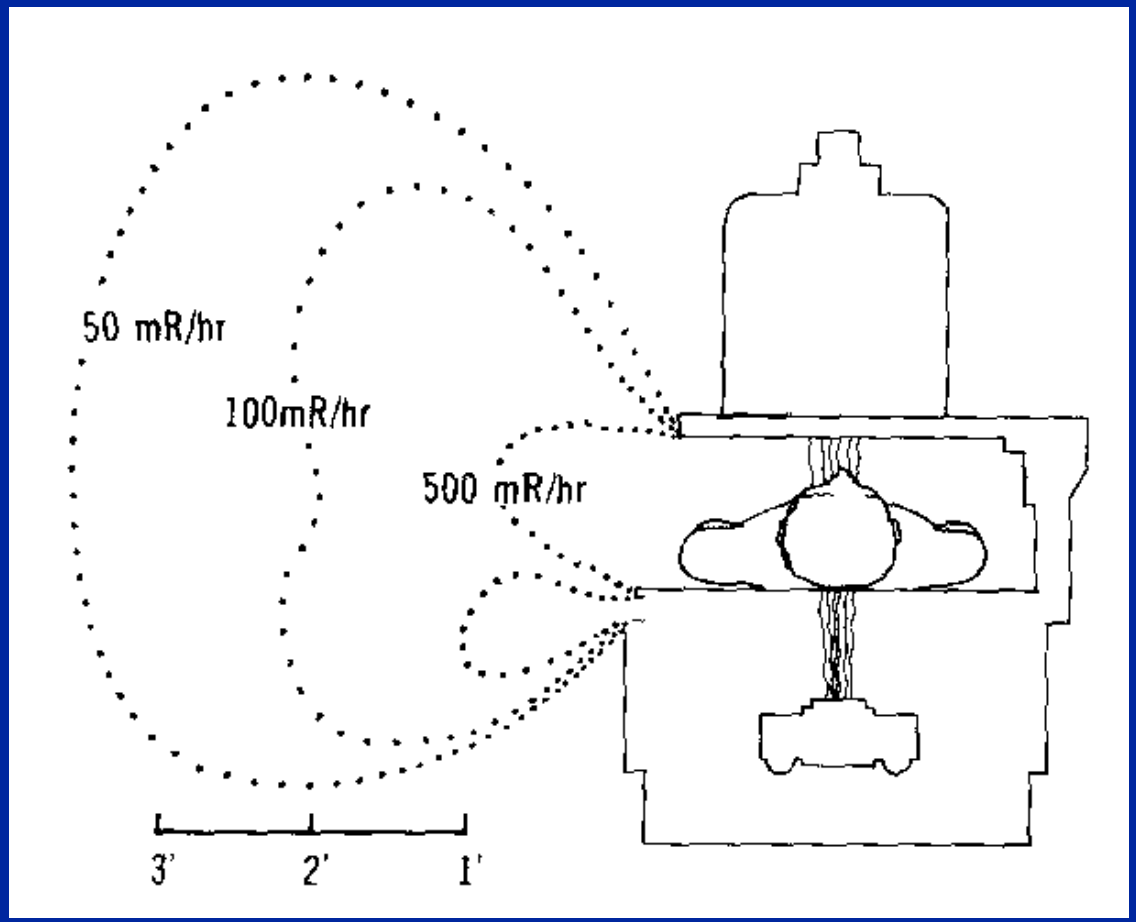


$$E_2 = E_1 \left[\frac{D_1}{D_2} \right]^2$$

Exposure Rate at 4 ft = (90 mR/hr)(2ft/4ft)^2 = 22.5 mR/hr.

Exposure Rate at 6 ft = (90 mR/hr)(2ft/6ft)^2 = 10 mR/hr.

Distance



- Portables must have 6’ long exposure switch cords

Shielding

- 0.25 mm lead equivalent
- Between radiologist and patient
- ➢ Exposures exceed 100 mR/hr @ 2 ft without drapes

Staff Protection

- Lead aprons (0.25 mm to 0.50 mm Pb)
  - 0.25 mm: absorbs > 90% of scatter
  - 0.35 - 0.50 mm: absorbs 95 - 99% of scatter
- Thyroid shields (similar to lead aprons)
- Leaded glasses
  - absorb 30 - 70% of scatter
- Ceiling mounted & portable barriers

Patient Protection

- kVp: High enough to penetrate patient.
- Field Size: Don't expose anatomy outside area of interest.
- Organ Shielding Shield reproductive organs.
- Geometry: Proper SSD.
- Image Receptors: Fast enough to minimize exposure without unacceptable level of noise.

Patient Protection

- Fluoroscopy: generally 1-2 R/min entrance exposure.
- Limit “on” time to reduce exposure.
- Last-image-hold reduces “on” time.
- Pulsed (vs continuous) fluoroscopy reduces dose.
- Require optimal image intensification system.
- Restrict field size.
- Magnification (higher mag = higher dose).

Conclusion

- Worker Ultimately Responsible
- Proper technique
  - Holding Patients, Proper Use of Portables, Contamination Control, etc.
- Proper Use of Dosimetry
- Reporting unsafe or non-compliant conditions

?Conclusion